Synthetic Biologic Membrane

STATUS QUO

- Membranes are part of all biological processes, and are used commercially in separation and purification processes.
- Membranes are used extensively in modern spacecraft for separations, sensors, space suits, and structures.
  - Current membranes have short lifespans and are susceptible to solids fouling and physical damage.
  - Biological membranes self-repair any damage through production of new membrane material, and have much longer life spans than non-bio membranes.
- Development of a synthetic biologic membrane capable of regenerating itself would reduce the mass and volume and increases the safety of future NASA missions .

NEW INSIGHTS

- Recent research into membranes for NGLS applications has identified a type of lipid based membrane that can function as a biomimetic structure. (zNano Inc.)
- Lipids are self assembling molecules that form the bases of biological membranes.
- Recent advances in synthetic biology allow organisms to over express lipids.
- Combining these organisms and membranes will create a synthetic biologic structure similar to the small intestine.
- This research is responsive to TA06-7 of the NASA Roadmap and is identified as a highest priority area by the NRC, Technology 6.1.2 Water, of ISBN 978-0-309-25362-8

PROBLEM / NEED BEING ADDRESSED

Membranes are used extensively in spacecraft design. Current membrane technologies are very susceptible to chemical, radiation, and physical damage. As a result, membrane technologies incur a sizable resupply penalty for long duration missions. This project will develop a synthetic biological membrane capable of regeneration. The initial focus of development will be a synthetic living membrane for water recycling.

PROJECT DESCRIPTION/APPROACH

The proposed research will develop a synthetic biologic membrane. This membrane will be designed to purify wastewater initially but will eventually be expanded to other space flight applications. Work will be completed in three years.

- The first year will evaluate the feasibility of the proposed approach by investigating the key risk. This risk is centered around finding a lipid formulation that can both be generated by an engineered organism and be used to produce a functional membrane. This work will support a go/no go decision at the end of the first year.
- The second year will develop an engineered organism and a membrane generated from lipids produced by this organism.
- In the third year we will integrate the engineered organism and the lip membrane to produce a living biomimetic structure that can be used in a wastewater treatment system

In the forth year (not funded as part of this activity) we will integrate this new membrane with the NGLS FOST or the SB BES. Funding for the forth year will be solicited from the NASA Advanced Exploration Systems (AES) program.

Implementation Phase (3 years, $1.8M/year):

Will provide funding to zNano Inc. and ARC to develop biologic membrane..

- ARC, Identify lipids than can be generated biologically and can be used to construct separation membrane.
- ARC, Demonstrate hyper expression of lipids via engineered microbes.
- zNano, Demonstrate fabrication of membrane from lipids generated from engineered organisms.
- ARC, Demonstrate growth of engineered microbes in OA solution.
- zNano/ARC, Demonstrate regeneration of lipid membrane when damaged physically and with radiation.
- zNano/ARC, growth of microbes on FO membrane.
- ARC, Demonstrate integration of lipid membrane and engineered microbes.
- ARC, Demonstrate function of integrated membrane.

QUANTITATIVE IMPACT

- Game changing-development of a synthetic biological organ that functions as a living machine.
- *Target - NGLS FOST integration demonstration in FY18.*
  - *Reduces* total mass of operating ISS UPA like function by about 400K/year.
  - Improves reliability and life span of membrane to more than 3 years
  - Saves crew time, 2 hrs/week.
- *The knowledge generated will also apply to use of living membranes in:*
  - *Air separations*
  - *brine drying*
  - *Synthetic biological Organs*
    - *Synthetic drug development*
    - *Synthetic sensors and synthetic memory*
    - *Living structure*

PROJECT GOAL

- Develop and testing of a synthetic biological membrane that performs life support functions.
  This synthetic organ will be similar to a small intestine in that it can purify wastewater, handle high solids feed, has no maintenance requirements, and has a life span of many years.
- Delivery of a prototype biological membrane for use FOST spacecraft water recycling system.
- Transfer technology to other applications such as inflatable structures, space suits, and other synthetic biological organs.
- TRL entry 2, TRL exit 4

Synthetic Biological Membrane Overview

What would you say to a Senator that you meet in the elevator? (3 sentences)
The ultimate goal of the Synthetic Biological Membrane project is to develop a new type of membrane that will enable the wastewater treatment system required on exploration missions to operate for extended periods while requiring no maintenance, and using only available resources. Because current water treatment systems have a lifetime of less than 1 year, extending membrane life will benefit exploration missions by reducing upmass and crew time requirements associated with maintenance and resupply/replacement of membranes. The project will use synthetic biology to engineer organisms that protect and replenish the membrane, and this new technology can be easily adapted for use in terrestrial waste water treatment plants.

Integration with other projects/programs and partnerships

- AES Life Support Systems- Mission Use Agreement signed at project level.
- Indirect: STTR Phase II - An End-To-End Microfluidic Platform; HJ Science & Technology, Inc.

Technology Infusion Plan:

- PC
- Synthetic Biological Membrane
- HEOMD (AES Life Support Technologies)/Industry
- Potential use for waste-water treatment in space and on Earth.

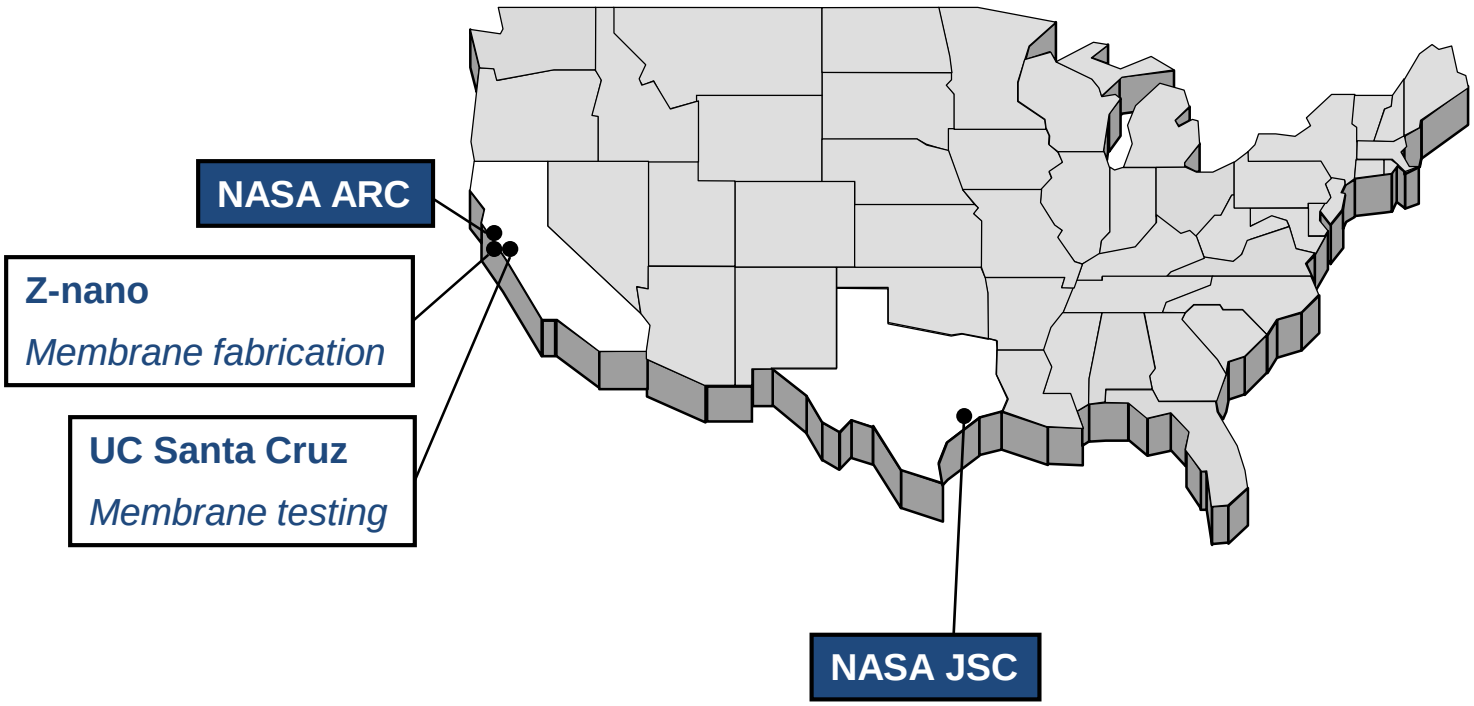
Key Personnel:

Program Element Manager: Wade May
Project Manager: Michael Flynn
Lead Center: NASA Ames
Supporting Centers: JSC
NASA NPR: 7120.8
Guided or Competed: Guided
Type of Technology: Push

Key Facts:

GCD Theme: ADSI
Execution Status: Year 1 of 3
Technology State Date: Oct 1, 2014
Technology End Date: Sept 30, 2017
Technology TRL Start: 2
Technology TRL End: 4
Technology Current TRL: 2
Technology Lifecycle Phase: Formulation (Phase A)

Synthetic Biological Membrane Organization and Key Members



Synthetic Biological Membrane Resources

Key Milestones:

Milestone	Baseline Date	Current Date	Comment
Lipid specification report for lipid down-select	1/15/15	1/15/15	Completed
Analytical protocols (QA/QC)	3/3/15	3/3/15	Completed
Non-Advocate Review	3/31/15	*9/15/15*	Completed
GLAMM Report	4/1/15	4/1/15	Completed

Quarterly Technical Accomplishments:

- Completed technical milestones
- Significantly reduced project risk associated with lipid engineering by changing technical approach. Instead of engineering organisms to produce specific lipids which may require extensive processing steps, organisms will produce fatty acids that can be excreted.

Concerns:

Cost	Schedule	Technical	Programmatic

Resources:

- FY2014: N/A
- FY2015: $1.86M
- FTE: 3.3 (3 ARC, .3 JSC)
- WYE: 3

Budget ($K)	Q1	Q2	Q3	Q4	Total
Budget Allocation	$ 1,860	$ -	$ -	$ -	$ 1,860
Program Authority/ Funds Distribution	$ 569	$ 1,227	$ -	$ -	$ 1,796
Obligated	$ 289	$ 566	$ -	$ -	$ 856
Costed	$ 202	$ 386	$ -	$ -	$ 587

Annual Budget Profile ($M)